II Biota Treatment Plants

A water treatment facility for the complete inactivation of all biological organisms will become a part of any feature proposed for water supply import to the Red River basin. This does not necessarily imply water will be treated to drinking water standards, however it does require a water supply that has been "sterilized" from all living organism. Since this treatment requirement will apply to several water supply features, a description of this water treatment process, and cost estimates, are presented here. This treatment process has not been designed to the point of construction specifications, however the process has been outlined with costs estimated for the major features and a relatively large percentage remaining in the unlisted items cost group. This cost estimate should provide adequate comparisons of various water supply features.

Description

To ensure compliance with the Boundary Waters Treaty of 1909, water from the Missouri River drainage basin, prior to delivery to the Red River drainage, must be pretreated to inactivate all aquatic biota, including fish, larvae, fish eggs, algae, viruses, bacteria, and protozoa. This requirement arises from the fact that the Missouri is part of the Mississippi drainage system, whereas the Red River drains ultimately to Hudson Bay; thus, any water transferred from one to the other crosses a major divide not only between drainage basins but also between ecosystems.

Many studies have been done to determine what treatment systems can meet this requirement and the costs of such systems. In December 1995 the North Dakota State Water Commission and the Garrison Diversion Conservatory District published the final report of the "Northwest Area Water Supply Project Chloramine Challenge Study" (1995 challenge study). This report verified the effectiveness of either chlorination/chloramine or ozonation to provide 99.9% (3-log) removal or inactivation of *Giardia lambia* cysts and 99.99% (4-log) removal or inactivation of viruses. The challenge study also concluded that suspended solids do not affect the disinfection power of ozone and chlorine/chloramine, thereby eliminating the need for sand filters.

In the pretreatment of imported water, the raw water would be disinfected near the intake or booster pump station, using either an ozone treatment system or a chlorine/chloramine system. An appraisal-level process design and cost estimate is provided for each of these systems. Disinfection design criteria used in this report are the same as those used for the 15-cfs Lake Audubon Intake/Pump Station/Pretreatment Facility of the Northwest Area Water Supply Study Project (NAWS). Appraisal level construction cost estimates were determined for a 135 CFS and 70 CFS system and prorated for the other flows needed in each import alternative.

Each system is sized to satisfy the design criteria for the flow demands discussed for the various features described in chapter 5. Operation of the plant at less than design flow would increase the detention time and increase the effectiveness of disinfection. This is ideal for the ozonation systems but may be a problem for the chorine/chloramine system, in which the amount of disinfection products produced increases with the amount of free chlorine contact time.

Construction costs presented in the summary report are those from the Bureau of Reclamation appraisal-level estimate. The operation and maintenance costs are a combination of the annual estimated costs for a low head pumping plant, determined by a Bureau of Reclamation program, and a prorated cost per CFS per day operation as determined from the Houston Engineering study for the NAWS Lake Audubon intake pump facility.

OZONATION AND CHLORAMINATION DISINFECTION SYSTEM

Description

The diagram on page 13 shows the process flow of an ozonation treatment system to treat the modeled import flows. In this system, water discharged from each low-head pump would flow through an automatic backwashing sediment filter, followed by a multiple-stage concrete contact tank, where it undergoes ozonation, oxidation, deozonation, and chloramination before discharge to a high-head pump for conveyance to the Red River watershed. At the peak flow rate, the system provides a 7-minute ozone detention time before deozonation. The concentration of ozone in the reaction portion of the tank is monitored, and if it declines below a set-point concentration — say, 1 ppm — the system automatically increases the ozone injection rate into the contact chamber. The automatic backwashing sediment filter will be used as needed to provide water at 5 NTU or less turbidity to the ozonation system. The filter would be by-passed if the source water turbidity is below 5 NTU.

The ozonation process begins with the liquid oxygen storage tank (LOX). The liquid oxygen feeds into the evaporators, which then discharge oxygen gas to the ozone generators. Ozone from the generators feeds into the fine-bubble diffusers, which bubble the disinfectant through the water column within the baffled contact tank. In order to protect the high-head treated-water pump from corrosion caused by dissolved ozone, air is bubbled into the water in the ozone reduction chamber, causing the ozone to diffuse from the water into the air. After deozonation, ammonia gas is bubbled into the water in the ammonia contact chamber, followed by chlorine gas injection into the discharge line from the pump. The ammonia and chlorine provide a chloramine residual of 2.5 mg/L to control biofilm development in the pipeline.

The pretreated water will need to be dechlorinated using a sulfur dioxide injection system prior to discharge or use. A drawback to the chloramine residual requirement is that, after dechlorination, the imported water will have an ammonia concentration of approximately 0.56 ppm, which will increase the oxygen demand at the point of discharge.

The following are disinfection criteria used to determine the required process equipment and costs for each alternative at the design demands:

- Ozone dosage 3 mg/L
- Ozone contact time 2 minutes
- Ozone reaction time 5 minutes
- Ozone reduction tine 5 minutes
- Ammonia dosage 0.56 mg/L
- Chlorine dosage rate 2.5 mg/L
- Chloramine Residual across the divide of 2.5 mg/L.
- Dechlorination to non-detect prior to discharge to Red River for 116.5 and 135 CFS alternatives only.

Published EPA contact time (CT) Values for 99.9 percent inactivation of Giardia Lambia Cyst by ozone require a CT of 0.48 to 2.9 minutes of which a CT value is required at water temperatures of below 1 degree Celsius. With a control set point of 1 ppm, the proposed systems would provide a CT of 7 minutes at the design flow rate which is approximately 2.4 times the required value to option log 3 (99.9%) reduction for Giardia and log 4 (99.99%) reduction of viruses.

Conceptual Design

Table 1 provides a summary of the conceptual design for ozone/chloramination pretreatment system for each alternative. The design and cost for a sulfur dioxide dechlorination system is included for all options to dechlorinate the water before discharge to the Red River, Lake Ashtabula or to the City of Fargo water treatment plant.

Due to the size and amount of pressurized chorine cylinders required and the size of the ozone generators, separate buildings for the ozone generators and chloramination systems are provided in the conceptual design. These buildings will be located adjacent to the concrete oxidation reaction tank and the intake pumping plant. For those alternatives that discharge disinfected water into surface waters, a dechlorination building which houses the sulfur dioxide cylinders and injection equipment will be required at the point of discharge.

Table 1 - Conceptual Design
Ozone and Chloramination

Description	Treated Water to the Headwaters of the Sheyenne - 116.5 CFS (52,285 gpm)	Treated Water to the Headwaters of the Sheyenne and Red River- 135 CFS (60,600 gpm)	Treated Water to Fargo- 70 CFS (31,500 gpm) & 79 CFS (35,400 gpm) optimizing alternative.
Low head Inlet pumping station that includes manually cleaned bar screens and vertical turbine pumps..	7 pumps each a rated at 15 CFS (7,500 gpm)	8 pumps each a rated at 17 CFS (7,600 gpm)	4 pumps each a rated at 17.5 CFS (7,900 gpm)
Supply of oxygen gas by LOX with evaporators	17,000 gal storage tank	17,000 gal storage tank	17,000 gal storage tank
Ozone Generators	Produce 1,884 pounds of ozone per day at design flow.	Produce 2,183 pounds of ozone per day at design flow.	Produce 1,135 pounds of ozone per day at design flow.
Baffled Ozone Contact Tank	Enclosed concrete tank with 20 foot side water depth and a surface area of 4,195 square feet.	Enclosed concrete tank with 20 foot side water depth and a surface area of 4,861 square feet.	Enclosed concrete tank with 20 foot side water depth and a surface area of 2,527 square feet.
Ammoniation System	Located in a separate ammonia building . 300 PPD demand supplied by a ammonia gas injection system from 2 - 1 ton cylinders	Located in a separate ammonia building . 400 PPD demand supplied by a ammonia gas injection system from 2 - 1 ton cylinders	200 PPD demand supplied by a ammonia gas injection system from 150 pound cylinders
Chlorination System	Located in a chlorine building 1400 PPD demand supplied by a chlorine gas injection system from 4 - 1 ton cylinders	Located in a chlorine building 1638 PPD demand supplied by a chlorine gas injection system from 4 - 1 ton cylinders	851 PPD demand supplied by a chlorine gas injection system from 2 - 1 ton cylinders
Dechlorination System	Located in a SO^2 building on the Red River. 1400 PPD demand supplied by a sulfur dioxide gas injection system from 4- 1 ton cylinders	Located in a SO^2 building on the Red River. 1638 PPD demand supplied by a sulfur dioxide gas injection system from 4- 1 ton cylinders	Not included as water would not be dechlorinated prior to delivery to Fargo Water Pretreatment Plant.

Operation and Maintenance

The requirement for certified operators and precess chemicals for the operation of the ozone or chlorine/chloramine disinfection plants would be determined by the amount the plant is operated per year. Components requiring routine maintenance are identified in table 2.

Table 2
Ozone/chloramine process units needing operation and maintenance.

System component and function	Maintenance and operation requirements
Liquid Oxygen Storage Tank with evaporators	Monitoring liquid levels and pressures and ordering delivery of LOX when low
Ozone generator. Generates ozone from oxygen supply system.	Clean reaction chamber once a year Replace tubes every 2 years
Ozone injector and booster pump - Injects ozone into the water at a rate to maintain a 1 ppm residual following the contact tank.	Booster pump replacement as needed.
Ozone contact tank - Allows time for total disinfection of the water.	None
Ozone residual monitoring system - Monitors ozone in water existing the contact tank and controls ozone injection rates.	Routine replacement of Teflon membrane and recalibration of measuring probe..
Ozone destruct unit - Removes and converts ozone that accumulates in the ozone contact tank to oxygen before discharge to the environment.	Replacement of Catalyst every 2 to 4 years
Chlorine feed gas and or chlorine liquid storage ton containers and feed systems.	1. Monitoring and replacement of high pressure cylinders as needed. 2. Preventative maintenance on self contained breathing systems. 3. Maintenance on chlorinators/ chlorine evaporators.
Ammonia feed gas or liquid - Source for ammonia.	1.Monitoring and replacement of high pressure cylinders as needed. 2. Maintenance on ammoniators/ ammonia evaporators.
Chlorine/Ammonia injectors and booster pump - injects chlorine or ammonia into water.	Booster pump replacement as needed.
Chlorine residual monitors - Measures, controls and records chorine injection rates and residuals.	Routine replacement of buffer.
Ambient chlorine concentration monitor and alarm . Warning at 1 ppm danger alarm at 3 ppm chlorine in the breathing space.	None. Factory calibrated

Cost Analysis

The ozone/chloramine disinfection system appraisal level capital construction and operation and maintenance costs for the range of selected flows, as extrapolated from the Lake Audubon intake and pretreatment plant study done by Houston Engineering are provided, in table 3.

For this study, annual operation and maintenance costs for each alternative are provided for two operation scenarios. The first scenario operates each plant at half of the design flow for eight months of the year, and one month at design flow. The second scenario operates each plant at full design flow for 12 months or 360 days. The appraisal level annual operating cost of this schedule is proved in table 3.

Table 3
Extrapolated Costs Ozonation/Chloramination Pretreatment

Import Option	Import Flows-CFS (Acre-ft/year)	Estimated Capital Construction Cost for Ozone Disinfection System.[1]	Operation and Maintenance (O&M) Costs [2]
Supply Treated Water to the Headwaters of the Sheyenne with Future Diversions to the Red River	135 (97,762)	$27,432,000	$536,625 annual O&M cost when operating for 8 months @ 67.5 CFS and 1 month @ 135 CFS $1,287,900 annual O&M cost when operating for 12 months at 135 CFS.
Supply Treated Water to the Headwaters of the Sheyenne River	116.5 (84,365)	$23,673,000	$463,088 annual O&M cost when operating for 8 months @ 58.25 CFS and 1 month @ 116.6 CFS $1,111,410 annual O&M cost when operating for 12 months at 116 CFS.

Optimizing flow to Lake Ashtabula	79 (57,209)	$16,053,000	$314,025 annual O&M cost when operating for 8 months @ 39.5 CFS and 1 month @ 79 CFS. $753,660 annual O&M) cost when operating for 12 months at 79 CFS.
Pipeline Directly to Fargo	70 (50,691)	$14,224,000	$278,250 annual O&M cost when operating for 8 months @ 35 CFS and 1 month @ 70 CFS $667,800 annual O&M cost when operating for 12 months at 70 CFS.

[1] Prorated from the estimated capital construction cost of $3,048,000 for the 15 CFS Lake Audubon Intake/Pump Station/Pretreatment for ozone disinfection as revised in the April 9, 1998 communique to Jim Lennington, North Dakota Water Commission This calculates to a capital cost of $203,200 per CFS of treated water.

[2] Prorated from the estimated annual O&M cost of $104,000 for the 15 CFS Lake Audubon Intake/Pump Station/Pretreatment estimate for the operation and maintenance of a ozone disinfection as revised in the April 9, 1998 communique to Jim Lennington, North Dakota Water Commission. This calculates as a O&M cost of $20.00 per CFS per day of operation. Prorated costs to operate the chloramine system are estimated at an additional $6.50/cfs per day. The total prorated pretreatment cost is estimate at $26.50 per cfs per day of operation.

In extrapolating estimated costs from a 15 cfs plant to the higher flow rates of 70, 79, 116 and 135 CFS, the cost benefits due to the increased scale of these plants are not considered. In an attempt to verify the extrapolated costs and account for scale, the Bureau of Reclamations has done an appraisal level capital construction cost estimate for each alternative. The results are provided in table 4 and pictorially shown in graph 1. Criteria used to develop the appraisal level design and costs are based on the conceptual design criteria as was used for the Lake Audubon Intake/Pump Station/Pretreatment Facility. The detailed cost estimation worksheet for each alternative is in the appendix. The estimated operation and maintenance costs for these plants are based on those table 3 with the addition of the operational and maintenance cost for a low head pumping plant.

Table 4
Bureau of Reclamation Appraisal Level Construction and Operation/ Maintenance Costs For Ozone/Chloramination Pretreatment

Pretreatment Option	Construction Cost (Annual Operation and Maintenance Cost)	Annualized Cost/ Acre-ft. [1]
135 CFS Discharged near the Headwaters of the Sheyenne River with diversions to the upper Red River	\$23,000,000 (\$ 1.960,000)[2]	\$36.83 [2]
120 CFS Discharged near the Headwaters of the Sheyenne River	\$21,000,000 (\$ 1,750.000)[2]	\$37.28 [2]
75 CFS Piped Conveyance to Lake Ashtabula	\$14,500,000 (\$ 1,120,000)[2]	\$39.67[2]
70 CFS Conveyed to Fargo WTP	\$14,000,000 (\$ 1,050,000)[2]	\$40.12 [2]

[1] Annualized cost for the BOR capital construction estimate and the prorated annual operating costs for 30 years at a discount rate of 6 7/8 %.

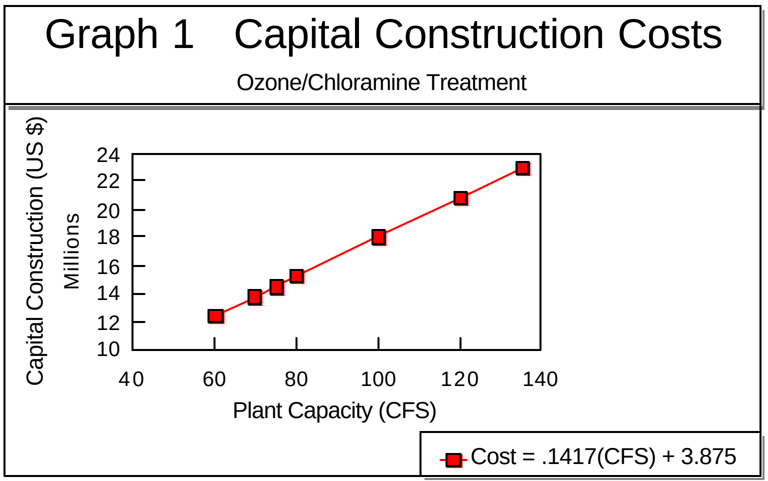
[2] When operating the pretreatment system 12 months of the year at the designed flow rate with the add-in for low head pumping plant. Based on the equation O&M = 14 x (cfs) +70.

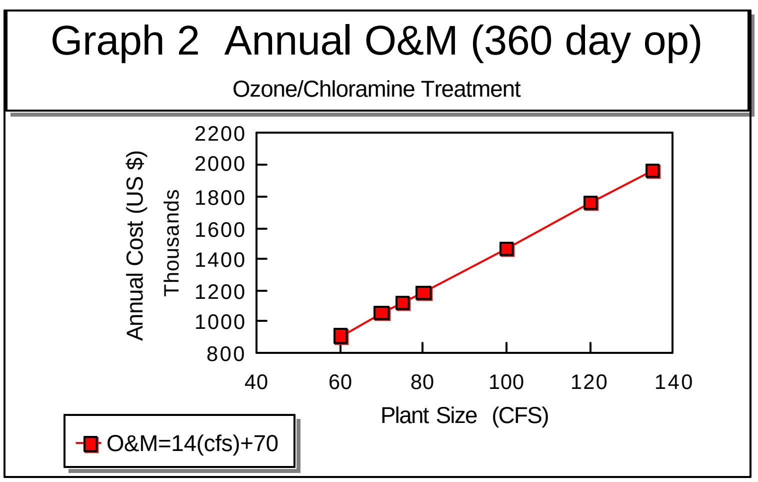
It is apparent when comparing the cost estimates between tables 3 and 4, that using extrapolating costs as presented for the 15 CFS Lake Audubon intake pump facility is a little more than the estimate for the construction costs of the larger flows required for the various Red River basin import water options. This difference in estimated construction cost is most likely caused by not including cost savings related to system scale up and the fact that the Lake Audubon intake pump facility costs includes a large concrete settling basin prior to the ozone contact basin that is not provided in the Red River import design.

Costs Used in Summary Report

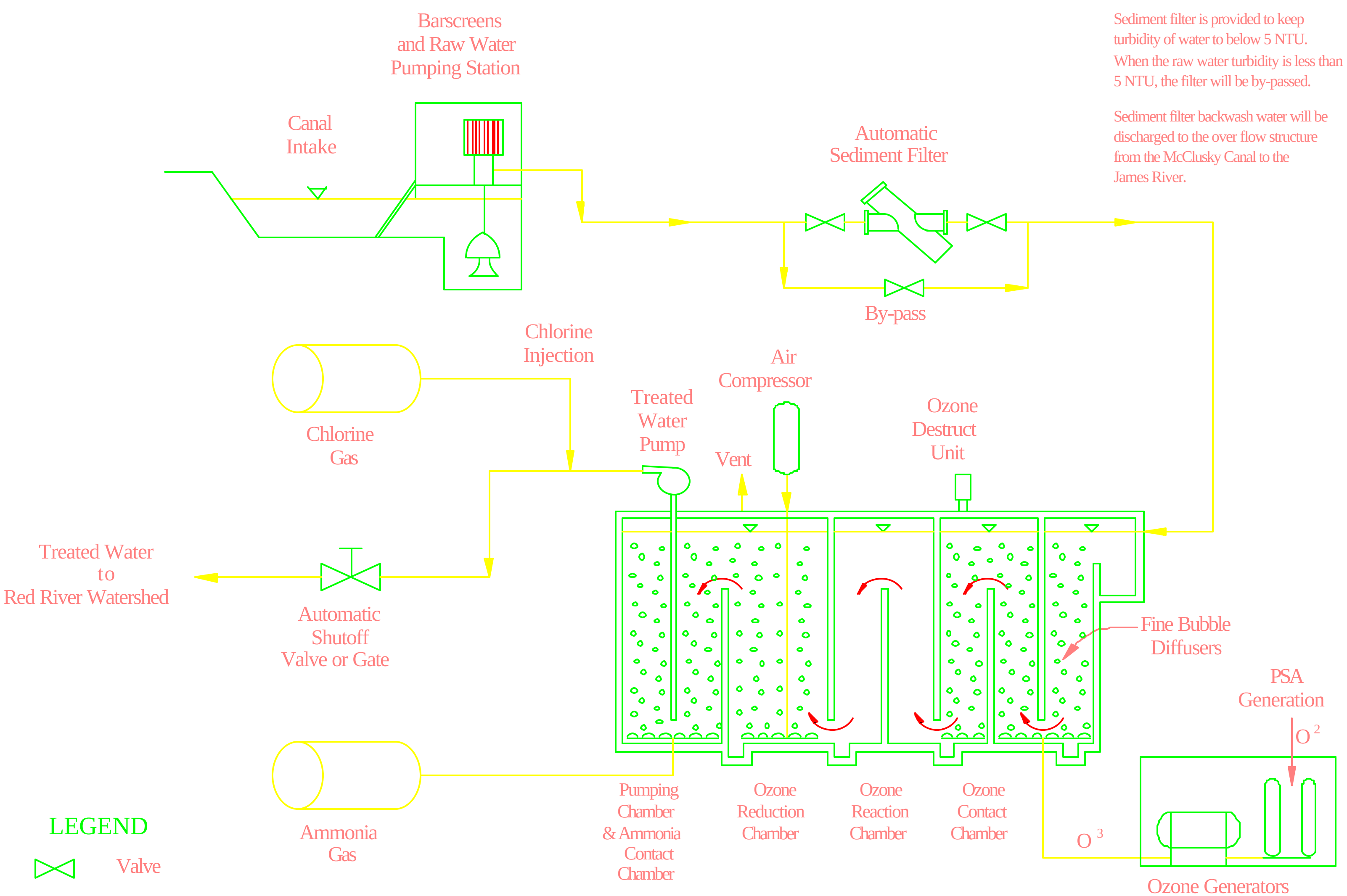
The ozone disinfection system appraisal-level capital construction and operation and maintenance costs for a range of selected flows are provided in graphs 1 and 2. Backup units for critical process units are included in the costs which includes an additional liquid oxygen storage tank that will provide adequate storage for 30 days and all chemical monitoring and feed systems.

Operation and maintenance of the ozone/chloramine pretreatment system will require certified operators. Actual costs for operators, chemicals and energy will be a function of the amount of time the pretreatment system is operated per year. Graph 2 presents the appraisal-level annual operating costs for operation of the treatment system at the design flow all year long. Costs are based on the prorated treatment estimate of $26.50 per CFS per day of operation plus the estimated cost to operate the low head treatment plant.





The estimated annualized cost (30 years at 6 7/8 percent) for operating the ozone/chloramine pretreatment system all year at the design flow ranges from $36.83/acre-ft for the 135-cfs system to $39.67/acre-ft for the 75-cfs system.



Ozone Disinfection System

CHLORINE/CHLORAMINE DISINFECTION SYSTEM

Description

This pretreatment system uses free chlorine to disinfect the water and a chloramine residual to reduce the development of disinfection byproducts. The results of the 1995 Challenge Study demonstrated that disinfection with a chlorine residual of 3.5 to 4.0 ppm for 5 minutes, followed by the addition of 1 part ammonia for every 4 parts of chlorine, followed by a chloramine detention time of at least 3 minutes produces a treated water that meets the biota reduction requirements for water being transferred from the Missouri River drainage to the Red River drainage. It achieves a 3-log reduction of giardia and a 4-log reduction in viruses while producing disinfection byproducts at concentrations less than the maximum allowed in existing (stage 1) and future (stage 2) regulations. A drawback to the use of chloramine for biofilm control is that after dechlorination the imported water will have an ammonia concentration of approximately 1 ppm, which will increase the oxygen demand at the point of discharge.
Figure 2 (Schematic of Chlorine/Chloramine Disinfection System)

The diagram on page 21 illustrates the process flow of the chlorination-chloramine treatment system described here. After sediment removal by the automatic backwashing filter, the water is chlorinated in the baffled free-chlorine contact tank, which provides 5 minutes of detention at peak flow. Free chlorine residual is monitored such that any concentration less than 4.5 ppm automatically increases the chlorine injection rate. Next, the water is detained in the ammonia contact chamber for 3 minutes, where ammonia gas is injected at concentrations of 1.1 to 1.25 ppm to form chloramine, and then it is pumped to the discharge point. A chloramine solution with a total chlorine residual of 4.5 ppm is maintained throughout the pipe. The pretreated water will need to be dechlorinated using a sulfur dioxide injection system prior to discharge or use.

The automatic backwashing sediment filter will be used as needed to provide water turbidity at 5 NTU or less to the chlorine/chloramine system and would be by-passed if the source water turbidity is below 5 NTU.

Disinfection criteria used to determine equipment size and costs are as follows:
- Free chlorine dose: 4.5 mg/L
- Ammonia dose: 1.125 mg/L
- Free chlorine contact time: 5 minutes
- Ammonia contact time in pumping chamber 3 minutes
- Chloramine Residual across the divide of 4.5 mg/L
- Suffer dioxide dechlorination rate: 4.5 mg/L

Conceptual Design

Table 5 provides a summary of the conceptual design for chloramination disinfection system for each alternative. The design and cost for a sulfur dioxide dechlorination system is included for the 135,116.5 and 79 CFS alternatives to dechlorinate the water before discharge to the Red River, Lake Ashtabula or the Fargo water treatment plant.

The chlorine cylinders, chlorinators and ammoniators will be contained in a separate building adjacent to the concrete oxidation reaction tank and the intake pumping station. For those alternatives that discharge disinfected water into surface waters, a dechlorination building which houses the sulfur dioxide cylinders and injection equipment will be required at the point of discharge.

Table 5
Conceptual Design
Chlorine/Chloramine Disinfection System

Description	Treated Water to the Headwaters of the Sheyenne - 116.5 CFS (52,285 gpm)	Treated Water to the Headwaters of the Sheyenne and Red River- 135 CFS (60,600 gpm)	Treated Water to Fargo- 70 CFS (31,500 gpm) and Optimizing flow to Lake Ashtabula
Low head Inlet pumping station that includes manually cleaned bar screens and vertical turbine pumps..	7 pumps each a rated at 15 CFS (7,500 gpm)	8 pumps each a rated at 17 CFS (7,600 gpm)	4 pumps each a rated at 17.5 CFS (7,900 gpm)
Baffled Chlorine and Ammonia Contact Tank	Enclosed concrete tank with 20 foot side water depth and a surface area of 2,800 square feet.	Enclosed concrete tank with 20 foot side water depth and a surface area of 2,800 square feet.	Enclosed concrete tank with 20 foot side water depth and a surface area of 1,700 square feet.
Ammonia Supply and Injection System	Located in a separate ammonia building . 700 PPD demand supplied by a 17,000 gallon tank with evaporators.	Located in a separate ammonia building 800 PPD demand supplied by a 17,000 gallon tank with evaporators.	Located in a separate ammonia building . 200 PPD demand supplied by a ammonia gas injection system from 150 pound cylinders
Chlorine Supply and Injection System	Located in a chlorine building 2,821 PPD demand supplied by a chlorine gas injection system from 6 - 1 ton cylinders	Located in a chlorine building 3275 PPD demand supplied by a chlorine gas injection system from 6 - 1 ton cylinders	Located in a chlorine building 851 PPD demand supplied by a chlorine gas injection system from 2 - 1 ton cylinders
Dechlorination and Injection System	Located in a SO^2 building on the Red River. 2,821 PPD demand supplied by a sulfur dioxide gas injection system from 6 - 1 ton cylinders	Located in a SO^2 building on the Red River. 3,275 PPD demand supplied by a sulfur dioxide gas injection system from 6 - 1 ton cylinders	Not included as water would not be dechlorinated prior to delivery to Fargo Water Pretreatment Plant.

Operation and Maintenance

Disinfection with chlorine/chloramine would require expertise with regard to operation and maintenance. Components requiring routine maintenance are identified in Table 6.

Table 6
Chlorine/chloramine process units needing operation and maintenance.

System component and function	Maintenance and operation requirements
Chlorine feed gas and or chlorine liquid storage ton containers and feed systems.	1. Monitoring and replacement of high pressure cylinders as needed. 2. Preventative maintenance on self contained breathing systems. 3. Maintenance on chlorinators/ chlorine evaporators.
Ammonia feed gas or liquid - Source for ammonia.	1.Monitoring and replacement of high pressure cylinders as needed. 2. Maintenance on ammoniators/ ammonia evaporators.
Chlorine/Ammonia injectors and booster pump - injects chlorine or ammonia into water.	Booster pump replacement as needed.
Chlorine residual monitors - Measures, controls and records chorine injection rates and residuals.	Routine replacement of buffer.
Ambient chlorine concentration monitor and alarm . Warning at 1 ppm danger alarm at 3 ppm chlorine in the breathing space.	None. Factory calibrated

Cost Analysis

Prorating the chlorine/chloramine costs from those determined by a 15 CFS Lake Audubon pumping plant may under estimate the cost of the import options discussed in this report. Using the above criteria for the treated water import flow rates would require a gas withdrawal systems from large pressurized tanks and a liquid withdrawal/evaporator system for the 116.5 and 135 CFS system. These systems may have a different construction cost than determined by the Lake Audubon system. This difference, if substantial, would be accounted for in the Bureau of Reclamation cost estimate.

The extrapolated appraisal level capital construction cost and annual operation and maintenance costs for the range of imported options are provided in table 7, graph 3 and graph 4.

Table 7

Extrapolated capital costs of chlorine/chloramine disinfection systems.

Import Option	Import Flows-CFS (Acre-ft / year)	Estimated Capital Cost for Chlorine/Chloramine Disinfection System [1]	Operation and Maintenance Costs [2]
Supply Treated Water to the Headwaters of the Sheyenne with Future Diversions to the Red River	135 (97,762)	$11,705,000	$236,925 annual O&M cost when operating for 8 months @ 67.5 CFS and 1 month @ 135 CFS $568,620 annual O&M cost when operating for 12 months at 135 CFS.
Supply Treated Water to the Headwaters of the Sheyenne River	116.5 (84,365)	$10,101,000	$204,458 annual O&M cost when operating for 8 months @ 58.25 CFS and 1 month @ 116.5 CFS $490,698 annual O&M cost when operating for 12 months at 116.5 CFS.
Optimizing flow to Lake Ashtabula	79 (57,209)	$6,849,000	$138,645 annual O&M cost when operating for 8 months @ 39.5 CFS and 1 month @ 79 CFS $332,748 annual O&M cost when operating for 12 months at 79 CFS.
Pipeline Directly to Fargo	70 (50,691)	$6,069,000	$122,850 annual O&M cost when operating for 8 months @ 35 CFS and 1 month @ 70 CFS $294,840 annual O&M cost when operating for 12 months at 70 CFS.

[1] Prorated from the estimated capital cost of $1,300,000 for the 15 CFS Lake Audubon Intake/Pump Station/Pretreatment estimate for Chlorine/Chloramine disinfection as provided by Houston Engineering in a letter to Jim Lennington, North Dakota Water Commission, on January 17, 1996. This calculates to a capital cost of $86,700 per CFS of treated water.

[2] Prorated from the estimated annual O&M cost of $64,000 for the 15 CFS Lake Audubon Intake/Pump Station/Pretreatment for the operation and maintenance of a chlorine/chloramine disinfection system as provided in a letter from Houston Engineering to Jim Lennington, North Dakota Water Commission, dated January 17, 1996. This calculates to $11.70 per CFS per day of operation.

To compare costing methods and account for scale the Bureau of Reclamations appraisal level cost estimate for each alternative is provided in table 8. The detailed cost estimation worksheet for each alternative is in the appendix.

Table 8
Bureau of Reclamation Capital Cost Estimates for Chlorine/Chloramine Pretreatment System

Pretreatment Option	Construction Cost (Annual Operation and Maintenance Cost)	Annualized Cost/ Acre-ft. [1]
135 CFS Discharged near the Headwaters of the Sheyenne River with Diversions to the upper Red River	$12,000,000 ($ 1,09,000)[2]	$19.90 [2]
120 CFS Discharged near the Headwaters of the Sheyenne River	$10,500,000 ($ 978,000)[2]	$19.90 [2]
75 CFS Piped Conveyance to Lake Ashtabula	$6,200,000 ($ 640,000)[2]	$19.92 [2]
70 CFS Conveyed to Fargo WTP	$5,700,000 ($ 603,000)[2]	$19.92 [2]

[1] Annualized cost for the BOR capital construction estimate and the prorated annual operating costs for 30 years at a discount rate of 6 7/8 %.

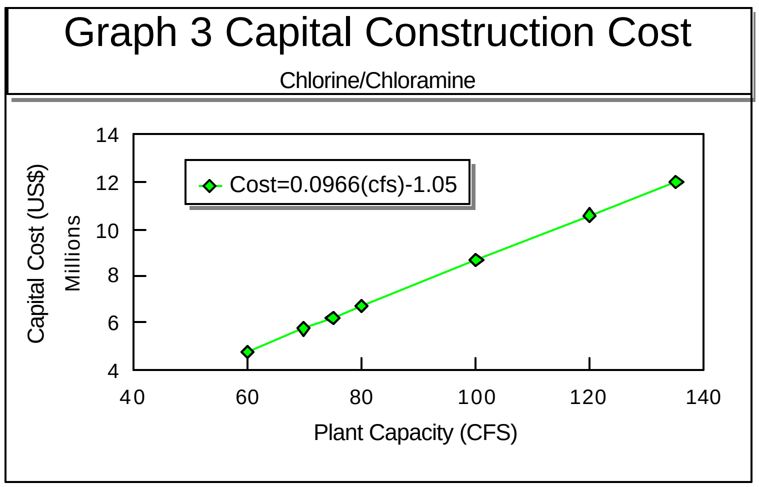
[2] When operating the pretreatment system 12 months of the year at the designed flow rate with the add-in for low head pumping plant. Based on the equation O&M = 14 x (cfs) +70.

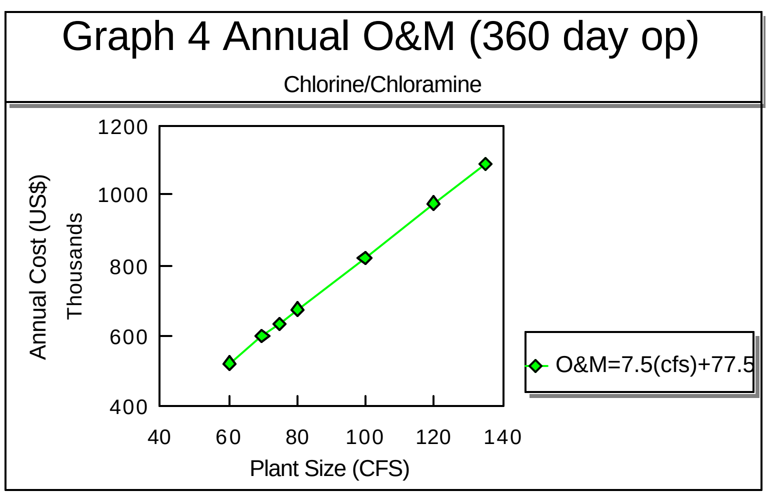
It is apparent when comparing the cost estimates between table 7 and 8, that using extrapolating costs as presented for the 15 CFS Lake Audubon intake pump facility will over estimate the construction costs for the larger flows required for the various Red River Basin import water options. This difference in estimated construction costs is most likely caused by not including cost savings related to system scale up and the fact that the Lake Audubon intake pump facility costs includes a large concrete settling basin prior to the ozone contact basin that is not provided in the Red River import treatment design.

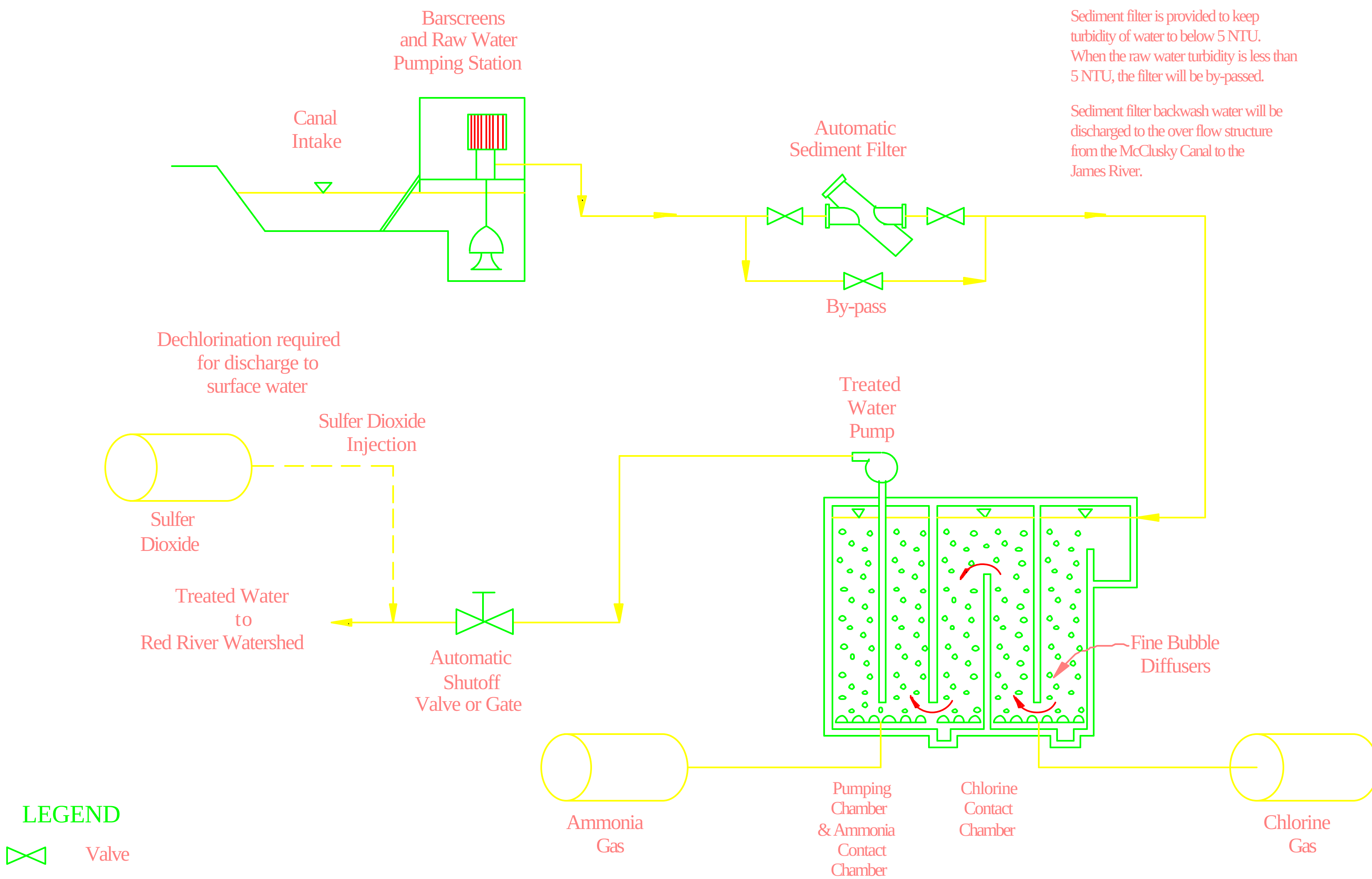
Costs Presented in Summary Report

The appraisal-level capital construction cost and annual operation and maintenance costs for the range of imported options are shown in graphs 3 and 4. Operation of the chlorine/chloramine disinfection system would require skilled operators. Actual costs for operators, chemicals and energy will be a function of the amount of time the pretreatment system is operated per year. Therefore, the O&M costs presented in graph 4 are based on the yearly operation of the plant at design flows. The estimate for the operation of the treatment system was prorated at $11.70 per day of operation as determined by the NAWS report.

The estimated annualized cost (30 years at 6 7/8 percent) for operating the chlorine/chloramine pretreatment system all year at the design flow ranges from $19.90/acre-ft for the 135 cfs system to $19.92/acre-ft for the 75-cfs system.







Chlorine/Chloramine Disinfection System

DECHLORINATION

Description

Chlorine in the imported water would have various adverse effects whether it is discharged to surface waters or delivered to a water-treatment plant. In order to reduce these effects, dechlorination facility will be required for all pretreatment systems. This facility would include a sulfur dioxide injection system which converts the chloramine compounds to ammonium sulfate and hydrochloric acid.

Table 9 identifies the equipment and expected maintenance for this system .

Table 9
Operation and Maintenance for Sulfur Dioxide Dechlorination systems.

System component and function	Maintenance and operation requirements
Sulfur Dioxide System feed gas - Source of dechlorination chemical.	1. Monitoring and replacement of high pressure cylinders as needed.
Sulfur dioxide injectors and booster pump - injects chlorine or ammonia into water.	Booster pump replacement as needed.
Sulfur dioxide residual monitors - Measures, controls and records chorine injection rates and residuals.	Routine replacement of buffer.
Ambient sulfur dioxide concentration monitor and alarm . Warning at 1 ppm danger alarm at 3 ppm chlorine dioxide in the breathing space.	None. Factory calibrated

DISCUSSION OF ALTERNATIVES

Ozonation followed by Chloramination

Ozone is a powerful oxidant and strong disinfectant, compared to free chlorine. Using this system would reduce the required contact time to meet the required log reduction for giardia and viruses.

Disinfection by-products (DBP) are a concern in all chemical disinfection systems. Presently the only regulated DBP of ozone is bromate, which is formed by ozonation of water containing bromide ion. Based on available information, bromide is not at detectable levels in the Missouri River drainage. During certain times of the year, organic material in the water may only be partially oxidized during ozonation, resulting in the formation of aldehydes. The type and concentration of aldehydes depend on the amount of organic matter, the amount of ozone used, and detention time for reaction. In the alternatives in which the treated water is discharged to the Red River and Lake Ashtabula, the formed aldehydes would be rapidly degraded by natural algae and bacteria. Water pumped directly to a municipal treatment plant may require activated carbon filters to remove aldehydes.

In this system, chloramination is required to eliminate biofilm growth in the conveyance system that could use the generated aldehydes as a food source. During plant operation at less than design flows, the resulting increase in ozone contact time would decrease the formation of aldehydes.

Chlorine/Chloramine Disinfection

This disinfection system would provide a 5 minute free chlorine residual contact time which would partially meet the disinfection requirements. The remaining contact time in order to provide a 3-log removal of *Giardia lambia* cysts and 4-log removal of viruses is accomplished by the weaker disinfectant chloramine during conveyance. In order to minimize the production of disinfection byproducts, the chlorine/chloramine disinfection system would need to operate at the design flows, since the disinfection products would increase as free chlorine detention times increase.

Table 10 is a summation of the Reclamation cost estimates for the ozone/chloramine/dechlorination and the chlorine/chloramine/dechlorination pretreatment systems for various alternatives that discharge into surface water within the Sheyenne River drainage basin.

CODE: D-8230

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE:	18-May-99	PROJECT:
Import - Water Treatment System 75 cfs and 70 cfs treatment options		Red River Needs Assessment Phase 2
		DIVISION:
Ozonation/chloramine LOX		FILE: J:\REDRIVER\RROWTP.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT	LIFE	Annual Operation	Annual Maintenance	Annual Replacement	Annual Energy	TOTAL ANNUAL
		Intake system to contact tank											
		Low head pumping plant (75 cfs, 50' head)		1	LS	$1,700,000	$1,700,000	35+	$45,000.00	$21,000.00		$145,000.00	$211,000.00
		30" diameter flanged pipe		120	LF	$200	$24,000	50+					
		30" diameter gate valve with motor operators		8	EA	$40,000	$320,000	50+					
		Magnetic flowmeters		4	EA	$10,000	$40,000	50+					
		Automatic sediment filters (100 micron, if needed)		4	EA	$55,000	$220,000	50+					
		Treatment System							$650,000.00				$650,000.00
		Ozone generators 1,135 PPD		2	EA	$1,300,000	$2,600,000	50+					
		Diffusers		205	EA	$100	$20,500	50+					
		70,000 gallon LOX tank with evaporators		2	EA	$600,000	$1,200,000	50+					
		Ozone Contact Tank (40'Wx80'Lx25'H), reinforced concrete		460	CY	$375	$172,500	50+					
		Excavation for ozone contact tank include dewatering		6,490	CY	$20	$129,800						
		Ozone residual monitor and control system		2	EA	$12,000	$24,000	50+					
		Ozone prefab building 40'Lx20'Wx10'H		800	SF	$150	$120,000	50+					
		Chlorination system 938 PPD											
		Chlorination system with manifold		1	EA	$10,000	$10,000	50+					
		1000 PPD proportional controller		2	EA	$4,000	$8,000	50+					
		Chlorine scale system for 2-ton containers		2	EA	$8,000	$16,000	50+					
		Chlorine/Ammonia building, 50'Lx20'Wx10'H		1000	SF	$150	$150,000	50+					
		210 PPD Ammoniator system											
		200 PPD Auto Switchover, 150# tank system		2	EA	$4,000	$8,000	50+					
		Dechlorination System - 938 PPD											
		Hardware with manifold		1	EA	$13,000	$13,000	50+					
		1000 PPD Proportional Sulphonator Controller		2	EA	$4,000	$8,000	50+					
		Sulfur Dioxide Scale System 2-ton cylinders		2	EA	$8,000	$16,000	50+					
		Sulfur Dioxide Ton Container Heater Blankets		2	EA	$5,000	$10,000	50+					
		Residual analyzer		2	EA	$4,000	$8,000	50+					
		Dechlorination Building 40'Lx20'Wx10'H		800	SF	$150	$120,000	50+					
								Subtotal	$695,000.00	$21,000.00		$145,000.00	$861,000.00
		Mobilization					$350,000				Unlisted Items (+/- 20%)		$169,000.00
		Subtotal					$7,287,800						
		Unlisted Items (+/- 20%)					$1,412,200				**TOTAL O, M, R, & E**		**$1,030,000.00**
		Contract Cost					$8,700,000						
		Contingencies (+/- 25%)					$2,300,000						
		Field Cost					$11,000,000						
		USBR Invest., Mitig., Engr., & Constr. Mgt.(+/-33%)					$3,500,000						
		TOTAL ESTIMATE					$14,500,000				**ANNUALIZED CAPITAL COST**		**$1,030,000.00**
											TOTAL ANNUAL COST		**$2,060,000.00**

QUANTITIES		PRICES	
BY Glenn Howard		BY Glenn Howard KCC K. Copeland	CHECKED KC 5/18/99
DATE PREPARED May 3, 1999	APPROVED	DATE 5/18/99	PRICE LEVEL

CODE:D-8230

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 18-May-99 Import - Water Treatment System 135 cfs and 116.5 cfs treatment options Ozonation/chloramine LOX	**PROJECT:** Red River Needs Assessment Phase 2 **DIVISION:** **FILE:** J:\REDRIVER\RROWTP.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT	LIFE	Annual Operation	Annual Maintenance	Annual Replacement	Annual Energy	TOTAL ANNUAL
		Intake System to Contact Tank											
		Low-head pumping plant (135 cfs, 50' head)		1	LS	$3,000,000	$3,000,000	35+	$45,000.00	$30,000.00		$255,000.00	$330,000.00
		48" diameter flanged pipe		80	LF	$400	$32,000	50+					
		30" diameter flanged pipe		240	LF	$200	$48,000	50+					
		30" diameter gate valve with motor operators		16	EA	$40,000	$640,000	50+					
		Magnetic flowmeters		16	EA	$10,000	$160,000	50+					
		Automatic sediment filters (100 micron, if needed)		8	EA	$55,000	$440,000	50+					
		Ozonation System							$1,300,000.00				$1,300,000.00
		Ozone generators 2,183 PPD		2	EA	$1,500,000	$3,000,000	50+					
		Diffusers		395	EA	$100	$39,500	50+					
		70,000 gallon LOX tank with evaporators		4	EA	$600,000	$2,400,000	50+					
		Ozone Contact Tank (50'Wx100'Lx25'H), reinforced concrete		700	CY	$350	$245,000	50+					
		Excavation for ozone contact tank include dewatering		8,850	CY	$20	$177,000						
		Ozone residual monitor and control system		2	EA	$12,000	$24,000	50+					
		Ozone prefab building 40'Lx25'Wx10'H		1000	SF	$140	$140,000	50+					
		Chlorination system 1820 PPD											
		2000 PPD Auto Switchover chlorinators & manifold		1	EA	$12,000	$12,000	50+					
		Automatic proportional controller		2	EA	$4,000	$8,000	50+					
		Chlorine scales for 4- ton cylinders		2	EA	$8,000	$16,000	50+					
		Chlorine building 70'Lx35'Wx10'H		2450	SF	$120	$294,000	50+					
		400 PPD Ammoniator auto-switch over system											
		Complete system is 2 - 200 PPD units		4	EA	$4,000	$16,000	50+					
		Dechlorination System 1820 PPD											
		2000 PPD Auto Switchover sulphonators & manifold		1	EA	$13,000	$13,000	50+					
		Proportional Controller		2	EA	$4,000	$8,000	50+					
		Sulfur dioxide 4-ton scale system		2	EA	$8,000	$16,000	50+					
		Ton Container Heater Blankets		4	EA	$5,000	$20,000	50+					
		Prefab SO2 building 40'Lx40'Wx10'H		1600	SF	$125	$200,000	50+					
								Subtotal	$1,345,000.00	$30,000.00		$255,000.00	$1,630,000.00
		Mobilization					$550,000				Unlisted Items (+/- 20%)		$330,000.00
		Subtotal					$11,498,500						
		Unlisted Items (+/- 20%)					$2,501,500				**TOTAL O, M, R, & E**		**$1,960,000.00**
		Contract Cost					$14,000,000						
		Contingencies (+/- 25%)					$3,000,000						
		Field Cost					$17,000,000						
		USBR Invest., Mitig., Engr., & Constr. Mgt.(+/-33%)					$6,000,000						
		TOTAL ESTIMATE					$23,000,000				**ANNUALIZED CAPITAL COST**		**$1,640,000.00**
											TOTAL ANNUAL COST		**$3,600,000.00**

QUANTITIES		PRICES	
BY Glenn Howard		BY Glenn Howard RKC K. Copeland	CHECKED DUMAAG 5/18/99
DATE PREPARED May 3, 1999	APPROVED	DATE 5/18/99	PRICE LEVEL

CODE:D-8230

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 18-May-99

Import - Water Treatment System

75 cfs and 70 cfs treatment options

Chlorine/Chloramine

PROJECT: Red River Needs Assessment Phase 2

DIVISION:

FILE: J:\REDRIVER\RROWTP.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT	LIFE	Annual Operation	Annual Maintenance	Annual Replacement	Annual Energy	TOTAL ANNUAL
		Intake system to contact tank											
		Low head pumping plant (75 cfs, 50' head)		1	LS	$1,700,000	$1,700,000	35+	$45,000.00	$21,000.00		$145,000.00	$211,000.00
		30" diameter flanged pipe		120	LF	$200	$24,000	50+					
		30" diameter gate valve with motor operators		8	EA	$40,000	$320,000	50+					
		Magnetic flowmeters		4	EA	$10,000	$40,000	50+					
		Automatic sediment filters (100 micron, if needed)		4	EA	$55,000	$220,000	50+					
		Chlorination System 1702 PPD							$320,000.00				$320,000.00
		2000 PPD Auto switchover chlorinator and manifold		1	EA	$13,000	$13,000	50+					
		Proportional Controller		2	EA	$4,000	$8,000	50+					
		Chlorine Scale System for 4-ton cylinders		2	EA	$8,000	$16,000	50+					
		Diffusers		375	EA	$100	$37,500	50+					
		Ammoniation System - 426 PPD											
		2 - 200 PPD Ammonia System		4	EA	$8,000	$32,000	50+					
		Chlorine/Ammonia Contact Tank - reinforced concrete		190	CY	$400	$76,000	50+					
		Excavation for ozone contact tank include dewatering		4,500	CY	$20	$90,000						
		Prefabricated Chlorine Building 40'Lx40'Wx10'H		1600	SF	$125	$200,000	50+					
		Dechlorination System - 938 PPD											
		Hardware with manifold		1	EA	$13,000	$13,000	50+					
		1000 PPD Proportional Sulphonator Controller		2	EA	$4,000	$8,000	50+					
		Sulfur Dioxide Scale System 4-ton cylinders		2	EA	$15,000	$30,000	50+					
		Sulfur Dioxide Ton Container Heater Blankets		4	EA	$5,000	$20,000	50+					
		Residual analyzer		2	EA	$4,000	$8,000	50+					
		Dechlorination Building 40'Lx20'Wx10'H		800	SF	$150	$120,000	50+					
								Subtotal	$365,000.00	$21,000.00		$145,000.00	$531,000.00
		Mobilization					$150,000				Unlisted Items (+/- 20%)		$109,000.00
		Subtotal					$3,125,500						
		Unlisted Items (+/- 20%)					$674,500				**TOTAL O, M, R, & E**		**$640,000.00**
		Contract Cost					$3,800,000						
		Contingencies (+/- 25%)					$900,000						
		Field Cost					$4,700,000						
		USBR Invest., Mitig., Engr., & Constr. Mgt.(+/-33%)					$1,500,000						
		TOTAL ESTIMATE					$6,200,000				**ANNUALIZED CAPITAL COST**		**$440,000.00**
											TOTAL ANNUAL COST		**$1,080,000.00**

QUANTITIES		PRICES	
BY Glenn Howard		BY Glenn Howard RKC K. Copeland	CHECKED 5/18/99
DATE PREPARED May 3, 1999	APPROVED	DATE 5/18/99	PRICE LEVEL

CODE:D-8230

ESTIMATE WORKSHEET

SHEET 1 OF 1

FEATURE: 18-May-99

Import - Water Treatment System

135 cfs and 116.5 cfs treatment options

Chlorine/Chloramine

PROJECT: Red River Needs Assessment Phase 2

DIVISION:

FILE: J:\REDRIVER\RROWTP.WK4

PLANT ACCT.	PAY ITEM	DESCRIPTION	CODE	QUANTITY	UNIT	UNIT PRICE	AMOUNT	LIFE	Annual Operation	Annual Maintenance	Annual Replacement	Annual Energy	TOTAL ANNUAL
		Intake System to Contact Tank											
		Low-head pumping plant (135 cfs, 50' head)		1	LS	$3,000,000	$3,000,000	35+	$45,000.00	$30,000.00		$255,000.00	$330,000.00
		48" diameter flanged pipe		80	LF	$400	$32,000	50+					
		30" diameter flanged pipe		240	LF	$200	$48,000	50+					
		30" diameter gate valve with motor operators		16	EA	$40,000	$640,000	50+					
		Magnetic flowmeters		16	EA	$10,000	$160,000	50+					
		Automatic sediment filters (100 micron, if needed)		8	EA	$55,000	$440,000	50+					
		Chlorination System 3275 PPD							$570,000.00				$570,000.00
		Chlorinators and manifold system		1	EA	$25,000	$25,000	50+					
		1000 PPD Proportional Chlorine Controllers		1	EA	$4,000	$4,000	50+					
		2000 PPD Proportional Chlorine Controller		2	EA	$4,000	$8,000	50+					
		Chlorine residual analyzer		2	EA	$4,000	$8,000	50+					
		Chlorine Scale System for 6 ton cylinders		2	EA	$10,000	$20,000	50+					
		Ammoniation System - 728 PPD											
		Manifold system		1	EA	$13,000	$13,000	50+					
		1000 PPD Proportional Ammonia Gas Controller		2	EA	$4,000	$8,000	50+					
		17,000 Ammonia Tank with Evaporator		2	EA	$45,000	$90,000	50+					
		Ammonia Tank Scale System		1	EA	$4,000	$4,000	50+					
		Diffusers		721	EA	$100	$72,100	50+					
		Chlorine Contact Tank - reinforced concrete		311	CY	$400	$124,400	50+					
		Excavation for ozone contact tank include dewatering		6,490	CY	$20	$129,800						
		Prefabricated Building 100'Lx40'Wx10'H		4000	SF	$100	$400,000	50+					
		Dechlorination System - 3275 PPD											
		Manifold System		1	EA	$13,000	$13,000	50+					
		1000 PPD Proportional Sulphonator Controller		1	EA	$4,000	$4,000	50+					
		2000 PPD Proportional Sulphonator Controller		2	EA	$4,000	$8,000	50+					
		Sulfur Dioxide Scale System 4 -ton containers		2	EA	$8,000	$16,000	50+					
		Sulfur Dioxide Ton Container Heater Blankets		4	EA	$5,000	$20,000	50+					
		Dechlorination Building 100'Lx40'Wx10'H		4000	SF	$100	$400,000	50+					
								Subtotal	$615,000.00	$30,000.00		$255,000.00	$900,000.00
		Mobilization					$280,000				Unlisted Items (+/- 20%)		$180,000.00
		Subtotal					$5,967,300						
		Unlisted Items (+/- 20%)					$1,232,700				**TOTAL O, M, R, & E**		**$1,080,000.00**
		Contract Cost					$7,200,000						
		Contingencies (+/- 25%)					$1,800,000						
		Field Cost					$9,000,000						
		USBR Invest., Mitig., Engr., & Constr. Mgt.(+/-33%)					$3,000,000						
		TOTAL ESTIMATE					$12,000,000				**ANNUALIZED CAPITAL COST**		**$860,000.00**
											TOTAL ANNUAL COST		**$1,940,000.00**

QUANTITIES		PRICES	
BY Glenn Howard		BY Glenn Howard KCC K. Copeland	CHECKED DCMaass 5/18/99
DATE PREPARED May 3, 1999	APPROVED	DATE 5/18/99	PRICE LEVEL

RAW WATER TREATMENT COST ANALYSIS

For the alternatives discussed in this report, the largest contributing factor to the cost of water treatment for the municipalities within the Red River Valley is water quality. Water quality has a direct effect on the cost of treatment via rules and standards that each municipality must comply. These include the Safe Water Drinking Act, the new Disinfection By-Product Rule, Surface Water Treatment Rule, and other rules that are in or will be in effect by as early as January 1, 2002. This analysis will primarily focus on the municipalities with the largest demand within the basin which includes the cities of Fargo and Grand Forks.

The extent of study involved with accurately determining costs associated with the treatment of the differing levels of water quality that would be set by each alternative is beyond the scope of this report. However, there is general understanding that water quality that exists for the import options would be greater than that which currently exists within the Red River Valley.
The data used for the purpose of determining the possible treatment costs were based on the current water quality found at both the Fargo and Grand Forks Water Treatment Plants as would exist in a no-action alternative. This would be considered to have the lowest water quality of all the alternatives studied within this report. All the alternatives that do not utilize the import of water are considered to be relatively the same as the baseline or to have only a slightly higher level of water quality.

Based on a comparison of water quality existing in the Missouri River Basin and the Red River Basin, it is assumed that the highest level of water quality would be realized by piping water directly from either the Missouri River or Lake Audubon to the municipalities of Fargo and Grand Forks. This direct piping will be considered to have the highest potential for treatment cost savings. All other alternatives that utilize the import feature will have a cost savings that fall somewhere between the direct piping and the no-action datum.

The following table shows a comparison between cities on the Missouri River and those on the Red River. The cost of chemical was used and the basis for cost comparison because it is the most directly affected by water quality. Other items such as labor, utility and operating costs were not used as part of the comparison due to lack of information and their relatively small impacts on the cost of treatment when comparing alternatives and water quality. The table shows only the current existing treatment costs and those that would be associated with piping water directly form the Missouri River at Bismarck to Fargo and/or Grand Forks.

Theoretical Chemical Cost Savings
Direct Treatment Without Mixing
11/17/99

	Bismarck	Mandan	Fargo	Grand Forks
Raw Water Treated				
1996 (Million Gallons)	3,044	872	4,171	2,906
1997 (Million Gallons)	3,622	914	4,030	2,747
1998 (Million Gallons)	3,481	907	4,203	2,994
Average (gal.)	3,382	898	4,135	2,882
Cost of Chemical				
1996	$353,928	$150,705	$838,514	$517,703
1997	$370,859	$150,936	$949,963	$510,520
1998	$332,510	$132,054	$1,097,450	$518,313
Average	$352,432	$144,565	$961,976	$515,512
Cost of Ozone kW (Fargo 98)			$37,075	
Cost / Million Gallons Treated Water	$104.20	$167.89	$241.64	$179.62
Theoretical Costs:				
Chemical for Fargo WTP to Treat Missouri River Water (97) *			$573,000	
Fargo Treatment of Missouri River Water / Million Gallon (97) *			$139	
Chemicals for Grand Forks WTP to Treat Missouri River Water (Avg.) **				$350,000
Grand Forks Treatment of Missouri River Water / Million Gallon (Avg.) **				$121
Savings:				
Treatment of Missouri River Water / 1MG			$103	$58
Total Annual Cost Savings to Treat Missouri River Water			**$426,051**	**$167,703**

*This information is from a Memorandum sent by Fargo City Engineer Robert Welton to Fargo Director of Public Works, Pat Zavoral, 11/25/96.

**This information was provided by Advanced Engineering, Steve Burian, P.E., in conjunction with the City of Grand Forks, 11/17/99.

	Yr 2050 Fargo Urban Area	Million Gallons Grand Forks	Chem Cost Annual Savings
Raw Surface Water Demand, Million Gallons (SEE NOTE 1)	16690	7736	
Alternative 5A @65 cfs Fargo area would receive 47 cfs	11090	0	$1,142,798
Alternative 6 @60 cfs, Fargo area would receive 42 cfs (SEE NOTE 2)	9910	0	$1,021,202
Alternative 7D, @20 cfs for Grand Forks (SEE NOTE 3)	0	4720	$274,633
Alternative 8 @21.3 cfs to Fargo urban area, 20 cfs to Grand Forks	5030	4720	$792,962

NOTE 1: Fargo Urban Area comprises Fargo, West Fargo, and Moorhead
NOTE 2: Used 50% of savings due to Red RIver mixing between Wahpeton and Fargo
NOTE 3: Alternatives 7abc no benefit due to mixing in Lake Ashtabula & Sheyenne River